Sea Turtle Strandings Along the Southeastern U.S. 1984-1991

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Abstract

A total of 5,241 dead turtles are documented in the Sea Turtle Stranding and Salavage Network for shrimp effort statistical zones 28-32 over the period 1984-1991. Of these 86% are loggerhead turtles, 6.5% are Kemp's ridley turtles, 4% are leatherback turtles, 3% are green turtles, and 1% are hawksbill turtles. For the loggerhead, Kemp's ridley, and green turtles, the majority of turtles were sub-adult and juvenile turtles. Most of the leatherback turtles were of adult size. For loggerhead turtles, there has been a shift in the mode of the size frequency distribution from 65cm to 55 cm from 1984-1991. It is hypothesized that this may reflect more turtles of the smaller size class in nearshore waters or may reflect an increase in the mortality rate on the smaller size class as compared to the 65 cm size class. Monthly estimates of mortality per unit of sampling effort (MPUE) were compared statistically with monthly estimates of shrimp trawl effort in offshore waters ("daysfished") and while there was a statistically significant positive relationship between these two variables, a much more statistically significant positive relationship was measured when comparing the cumulative monthly values for these two variables.

Introduction

The primary anthropogenic cause of mortality of sea turtles in the southeast U.S. is purported to be from commercial bottom trawl shrimp fishing (Henwood and Stuntz 1987; Magnuson et al. 1990). Henwood and Stuntz (1987) and Magnuson et al. (1990) estimated total mortality based on direct observations on commercial shrimp trawling vessels and on research trawls on the primary shrimp grounds. With the promulgation of regulations requiring commercial shrimp vessels to include federally certified turtle excluder devices (TEDs) in all nets, there arose a need to evaluate the effectiveness of these regulations in reducing turtle mortalities. While direct observation onboard commercial vessels is the optimum approach to estimating shrimp trawl related mortalities, it is also expensive. One alternative to evaluate mortalities is to develop an index of mortality which can be evaluated temporally and spatially. One approach to provide an index to evaluate shrimp trawl mortality is provided by sampling for stranded turtles in a way that provides results that are representative of mortality caused by shrimp trawling.

Beginning in 1980, the Southeast Fisheries Science Center (SEFSC) of the National Marine Fisheries Service (NMFS) implemented a voluntary sampling program directed at counting stranded turtles to be used to index turtle mortality along the Atlantic and Gulf of Mexico seaboards. This program is called the

Sea Turtle Stranding and Salvage Network (STSSN) and is administered by the SEFSC. While sampling was sporadic through 1983 in some areas, in 1984 many states implemented systematic sampling simply as a consequence of implementing systematic nesting beach surveys. In 1987, the SEFSC began supporting systematic surveys within selected areas to specifically evaluate the impact of regulations requiring offshore shrimp trawl fishermen to include TEDs in all nets. The original objective of this program was to provide data that could be used to evaluate the effectiveness of TEDs at reducing turtle mortality. However, full TED regulations did not go into effect until 1991. This sampling program continues to ensure a sufficient time series is available to fully evaluate pre-TED versus post-TED mortality. However, it is important to evaluate these data as a mechanism to measure a statistical relationship between offshore shrimp fishing and the occurrence of strandings. The objective of the current paper is to evaluate the use of stranded turtle counts as an approach to index turtle mortality along the southeast U.S. Atlantic coast.

A second objective is to provide a descriptive analysis of the species and size composition of turtles in the current stranding data base for the southeast U.S. Atlantic coast. This information may reflect the species and size composition of turtles in the nearshore waters of the southeast U.S. Atlantic. In addition, shifts in the size composition of stranded turtles by species over time may provide insight into the relative status or change in status of a given species. This is particularly important because turtles in the wild spend the majority of their lifetimes in the water and sampling over or in the water can be difficult and expensive. Therefore, it is imperative that as much information as possible be derived from turtles on land, whether dead or alive.

Methods and Materials

The data selected for analyses were those collected from zones 28-32 (Figure 1). These areas are the shrimp effort statistical zones identified by the then Bureau of Commercial fisheries and are defined by degree latitude which constitutes the southern boundary for each area or zone (Figure 1). All zones have been systematically sampled, at least during the spring and summer, for several years previous to 1984. Additional systematic surveys supported by the SEFSC were initiated in 1987 with the exception of zone 30. Zone 30 was included beginning in December 1988 as a result of a large number of turtles that washed ashore from October 1988 through February 1989. Details on the sampling methodology are described in Thompson and Martinez (1990). Data were collected by the states of Florida, Georgia, and South Carolina over the study area and are maintained by the STSSN as described originally by Schroeder (1989).

Total strandings were classified by species by year and by sampling zone. Size composition for each species was determined using straight line carapace length. For each species, sufficient measurements of both curved and straight line length were available to determine the linear relationship between these two measurements. As a result, all curved carapace lengths were converted to straight carapace length measurements.

Monthly total turtle mortality per unit of coastal sampling effort (MPUE) was estimated as in Thompson and Martinez (1990). Values of MPUE were not stratified by species. Only strandings and bottom shrimp trawl fishing effort data reported for the oceanic coast ("offshore") were included. Monthly values of MPUE were compared to monthly total offshore commercial shrimp trawl effort measured in days fished. One day fished represents a 24 hour period that all nets are in the water. This value, total daysfished, represents the maximum time that a turtle could be submerged while in a shrimp trawl.

To determine if there was a relationship between the occurrence of turtle strandings and the occurrence of shrimp trawling, a least squares linear regression was completed using the monthly MPUE value as the dependent variable and the monthly total offshore daysfished as the independent variable. Zone was used as a weighting variable to account for the increasing discreetness of the fishing season from south to north along the coast.

To evaluate the relationship between the accumulation of fishing effect and strandings, a least squares linear regression was completed using the cumulative monthly totals of MPUE and daysfished as dependent and independent variables respectively. Again, zone was used as a weighting variable to account for seasonality of shrimp trawling.

Results

A total of 5,241 turtles representing five species were reported to the STSSN from 1984 through 1991. Of these, 86% (4,482) turtles were identified as loggerhead turtles; 6.5% (344) as Kemp's ridley turtles; about 4% (240) as leatherback turtles; 3% (167) as green turtles; and less than 1% (8) as hawksbill turtles. Because there were so few hawksbill turtles, this species was exluded from further analyses.

The total frequency of strandings by year and species is presented in Figure 2. The annual number of reported strandings has been consistently higher than the 1984 total with a peak in 1987. Loggerhead turtles were consistently the dominant species in all years (Figure 2). In 1988, 1989, and 1990, the Kemp's ridley turtle was the next most numerous; and in 1987 and 1991, the leatherback turtle ranked as the second most numerous species (Figure 2). In 1984 and 1985, the green turtle was the second most numerous reported to the STSSN and in 1986, the Kemp's ridley and green were equally represented and the second most numerous in the STSSN database (Figure 2). Over the period 1984-1991, the Kemp's ridley increased in reported abundance for zones 28-32 (Figure 2).

The total number of strandings were classified by species and sampling zone (Figure 3). The loggerhead turtle dominated species composition within each zone and the green turtle was the second most abundant turtle reported in zone 28, the southermost area. In zone 29, both the leatherback and Kemp's ridley were ranked second in abundance. In zones 30 and 31, the Kemp's ridley ranked second in abundance and in zone 32, the northernmost area, the leatherback turtle ranked second in abundance (Figure 3). The green turtle which ranked second in abundance in zone 28 was essentially absent in zone 32 (Figure 3).

Straight line carapace lengths as measured or estimated from the resulting species specific regression equation were classified by 10 cm. increments. The regression equations between straight line carapace length (slcl) and curved length (cl) are shown in Table 1. The linear relationship was highly significant for all species.

The resulting frequency distributions of straight line carapace length by species were pooled over all five zones and classified by 10 cm increments (Figures 4). The cumulative frequency distributions are included with arithmetic mean, median and approximate mode. The modal size class for the loggerhead turtle is the 70 cm interval; the 40 cm. interval for the Kemp's ridley turtle; the 40 cm. interval for the green turtle; and the 130 and 160 cm. intervals for the leatherback turtle (Figures 4). The respective medians of the cumulative distributions by species are: 63.58 cm for the loggerhead turtle; 37.32 cm for the Kemp's ridley turtle; 32.57 cm for the green turtle; and 149.80 cm for the leatherback turtle (Figures 4). For the loggerhead, Kemp's ridley, and green turtles, the majority of strandings were less than the average mature straight length. However, for all species, including the Kemp's ridley, there were some turtles that were within the mature adult size class. According to Marquez (personal communication, March 1992), Kemp's ridley turtles emerge on Rancho Nuevo beaches as small as 50 cm straight length. Turtles equal to and greater than 50 cm. straight carapace length are well represented in the STSSN data base (Figure 4).

The bimodal distribution for the leatherback turtle may or may not be meaningful because of the relatively small sample size. However, the median length for our sample was greater than the average adult size as reported by Marquez (1990) of 125 cm. (Figure 4).

A comparison of annual size frequency distributions for loggerhead turtles was completed. The annual sample size for the loggerhead turtle was sufficient for this analysis (Figure 5). Beginning in 1984, the modal value is in the 65 cm interval. In 1985, the mode is 65 cm., and there is an increase in the percent of the total within the 55 cm interval as compared to 1984. In 1986, the mode is 75 cm. and there remains a large proportion in the 55 cm interval. In 1986, the proportional representation of turtle in the 55 cm interval is much smaller than in the previous two years. In 1987, the mode is the 55 cm interval and in 1988, the proportion of turtle in the 55 and 65 cm intervals is nearly equal. In 1991, the 65 cm interval is the mode and a large proportion of turtles were in the 55 cm interval. In 1989, the proportional representation of turtles in the 85 cm interval is large. In 1990, the mode is 55 cm. and 65 cm included a large proportion of turtles. In 1991, 55 cm. remains the modal interval. Over the period 1984 through 1991, there is a shift in the mode of reported stranded loggerhead turtles from 65 cm (60.0 to 69.9 cm) to 55 cm (50.0 to 59.9 cm).

The monthly estimates of MPUE and daysfished were evaluated and compared by pooling values over zones to optimize sample sizes. Monthly estimated MPUE by zone is shown in Figure 6. The largest estimated MPUE was for April and May in zone 31. Estimates of MPUE are low for all zones from June through September. In October, MPUE increased particularly in zone 29 and increased in zones 29 and 30 in November and December.

The total monthly daysfished were summed by zone (Figure 6). On an annual basis, the shrimp trawl fishing season appears to begin in April and peaked from September through December for all zones, although shrimp trawling has been relatively low in zone 28 and relatively high in zones 31 and 32.

The monthly estimates for MPUE and daysfished pooled over zone are compared in Figure 7. With unpooled data, a statistical comparison of monthly estimates produced a non-significant result based on a linear least squares regression of MPUE versus total daysfished for the offshore fishery and weighted by zone ($r^2 = .0008$, $F = .20$, $p = .6591$, $n = 240$). To improve the linear fit, the natural log of MPUE was regressed against the natural log of total daysfished and weighted by zone. Results of the log MPUE versus log daysfished regression were statistically significant at $p=.0129$ ($r^2=.0305$, $F=6.30$, $n=240$).

The cumulative monthly estimates for MPUE and daysfished were compared in Figure 7. To determine if there is a statistical relationship between cumulative shrimping effort and strandings pooled over zones, a least squares linear regression was completed. In this analysis, monthly cumulative MPUE was regressed against monthly cumulative daysfished. Results indicate a statistically significant relationship with $r^2=.7892$, $F=37.43$, and $p=.0001$. This analysis demonstrates a strong statistical relationship between cumulative strandings and shrimping effort for offshore waters of the Atlantic.

Discussion

The STSSN data base represents the longest continuous time series of data on sea turtles maintained by NMFS. Because of the continuity of this data base, these data have played a significant role in the development of management plans that promote species recovery. A major limitation of these data is that cause of death is very difficult to assign due to 1) the rapid decomposition of tissues and 2) confusion as to whether an event, for example, entanglement in gear occurred before or after death. However, the occurrence of strandings, particularly large numbers of strandings, in conjunction with a measureable anthropogenic activity provides circumstantial evidence of cause and effect. This result was demonstrated by Magnuson et al. (1990).

There is a very strong statistical relationship between the accumulation of strandings on a monthly basis and shrimp trawl effort as measured in daysfished. This statistical relationship supports the hypothesis that the seasonal onset of offshore strandings is the result of the onset of seasonal offshore shrimping. as described by Magnuson et al. (1990) and Caillouet, Jr. et al. (1991). These analyses all demonstrate that the use of stranding counts is a valid index to monitor turtle mortality and with sufficient sampling can be used to identify statitical relationships which may provide insight into cause and effect.

Currently, the status of turtle species is evaluated based on the numbers of females nesting on a beach. If strandings reflect the turtles present in nearshore waters, then changes in the size frequency distribution of turtles in the stranding data base reflect changes in the size frequency of turtles in the wild. Shifts in size frequency distributions over time may be used to identify changes in size specific mortality. As such, the stranding network provides information vital to monitoring trends in turtle stocks.

An evaluation of size frequency distributions was possible for the loggerhead, Kemp's ridley, and green turtles which demonstrate a nearshore life history stage. Results for loggerhead turtles by year demonstrated a shift in the modal value from 65 cm to 55 cm from 1984 to 1991, although this the mode changed in the interim. One hypothesis to explain this change is that over this period there were more turtles in the 55 cm size class in 1991 than in 1984 which may be the result of beach protection. An alternative hypothesis is that mortality on the 55 cm size class was higher than the 65 cm year class in 1991 than in 1984.

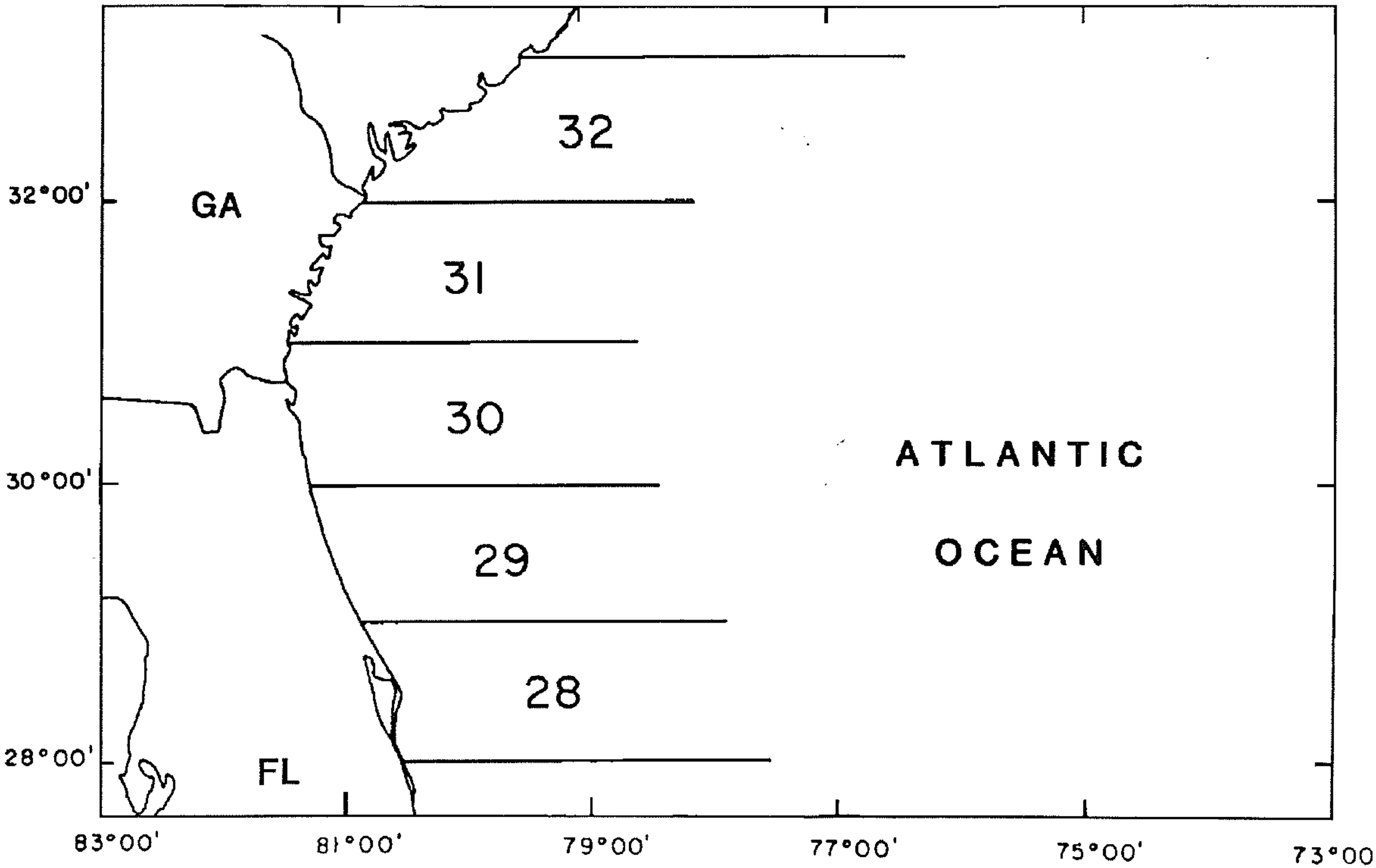
The modal value for size frequency distribution may be the size that turtles are fully recruited to the nearshore waters. If this is true, then the use of strandings for the Kemp's ridley, loggerhead, and green turtles does reflect the size and species composition of turtle in nearshore waters. Shifts in the composition of turtles by species in the data base then reflect changes in the species composition of turtles in the wild which also may be an index of decline or recovery. These types of changes, shifts in the frequency distribution by size and species in the nesting population may also provide similar insights more rapidly than enumerating change in nesting females.

Typically, stranding data are used for the documentation of deaths. However, these data may provide information on the status of populations. It is apparent that the continuation of this data base is important .

Acknowledgments

The estimates of MPUE were provided by Anthonly Martinez, SEFSC Maimi. The STSSN coordinator for the SEFSC is Wendy Teas. The data were collected by numerous members of their respective state stranding networks to Sally Murhpy, South Carolina State Coordinator, Charles Maley, Georgia State Coordinator, and Barbara Schroeder, Florida State Coordinator. Dr. Joseph Powers and Dr. Bill Richards provided input to improve the manuscript.

List of Figures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GA
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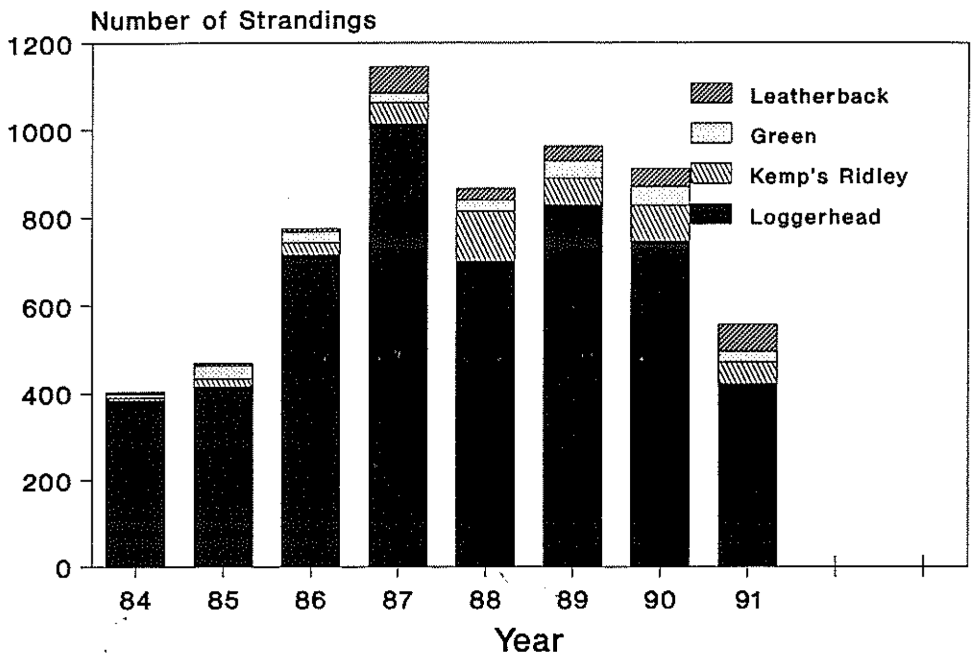
Figure 1



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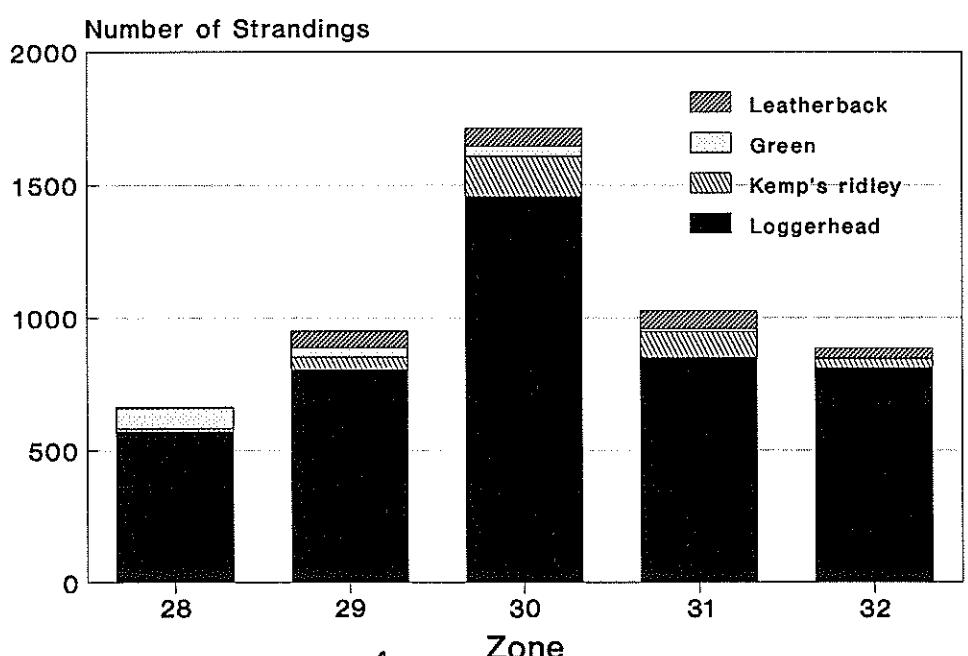
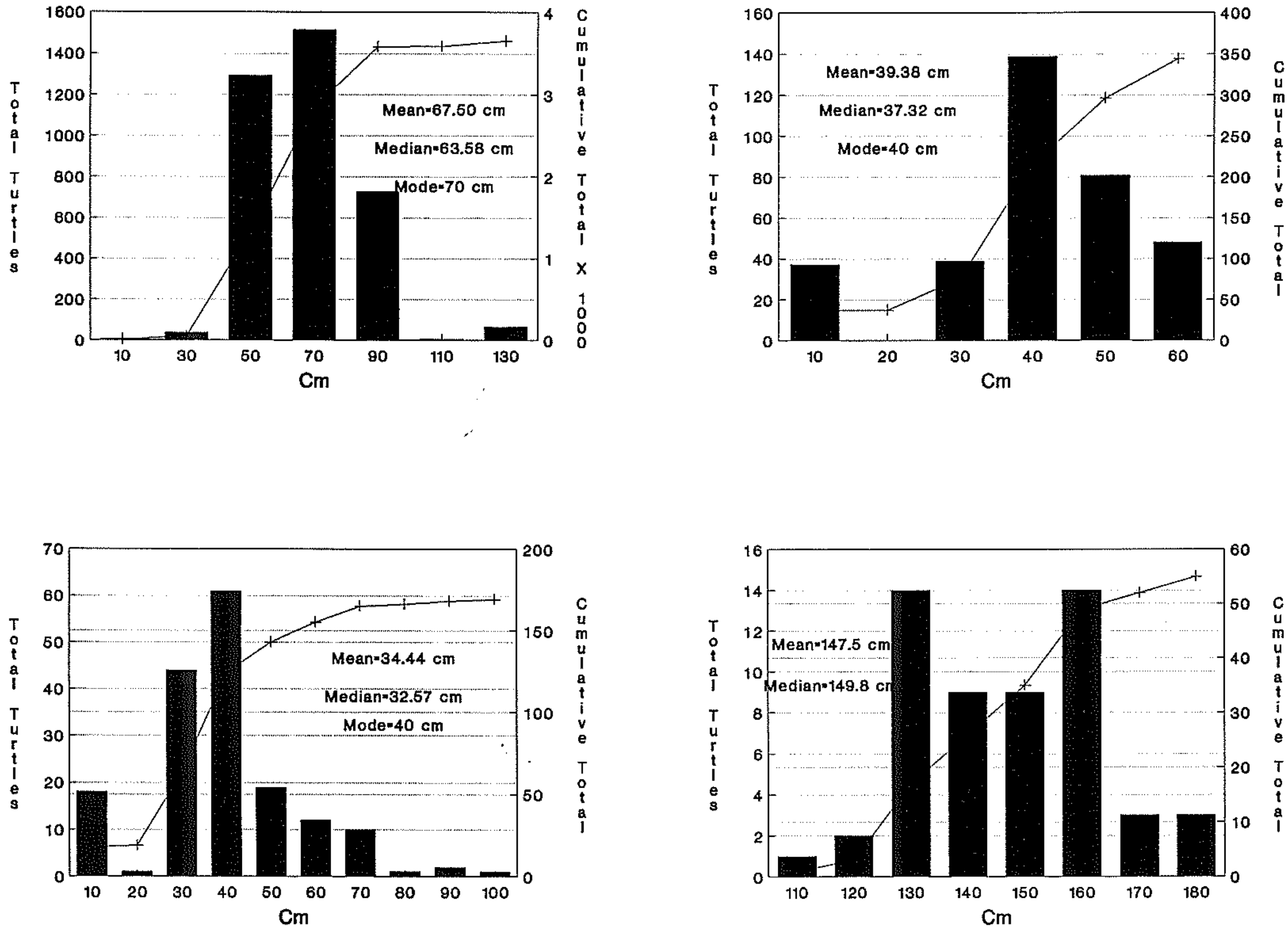


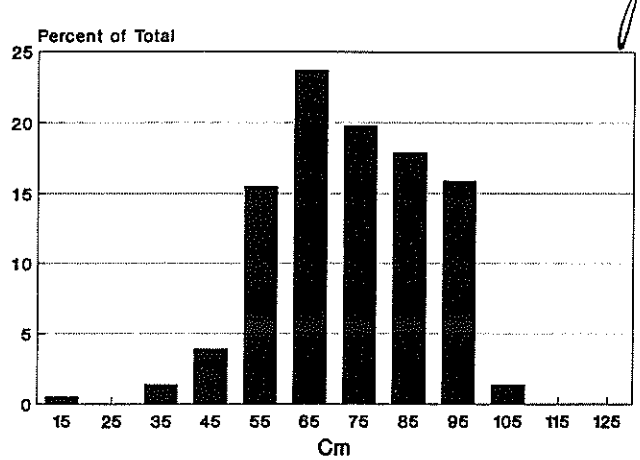
Figure 3

Figure 4.



Total Turtles
Cumulative Total X 1000
Mean=67.50 cm
Median=63.58 cm
Mode=70 cm
Cm
Total Turtles
Cumulative Total
Mean=39.38 cm
Median=37.32 cm
Mode=40 cm
Cm
Total Turtles
Cumulative Total
Mean=34.44 cm
Median=32.57 cm
Mode=40 cm
Cm
Total Turtles
Cumulative Total
Mean=147.5 cm
Median=149.8 cm
Cm

figure 8


Percent of Total
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15
10
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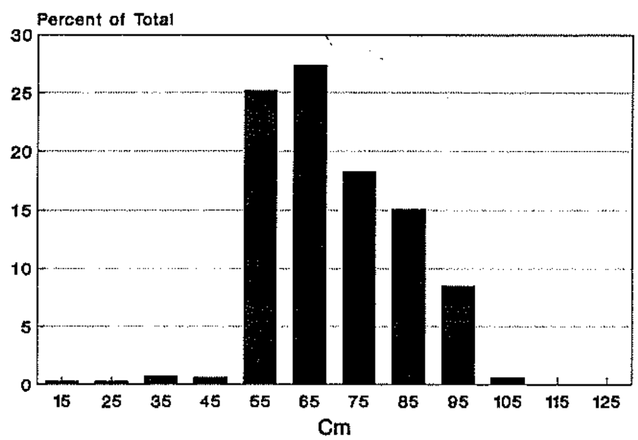
Cm


Percent of Total
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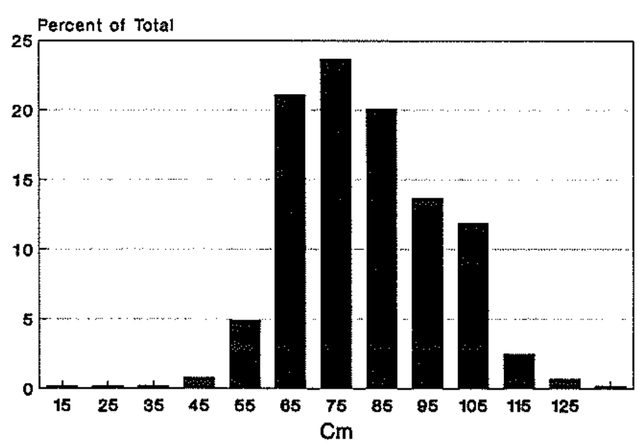
Percent of Total
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15 25 35 45 55 65 75 85 95 105 115 125
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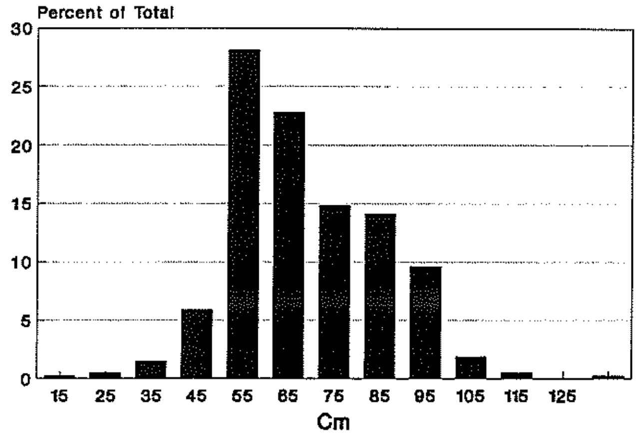
5 (cont)



Percent of Total
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15 25 35 45 55 65 75 85 95 105 115 125
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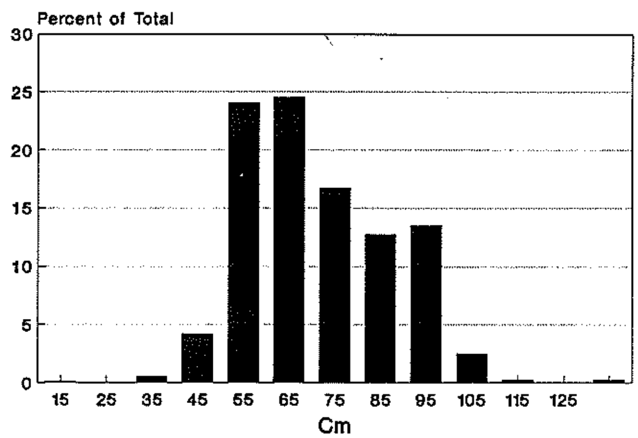

Percent of Total
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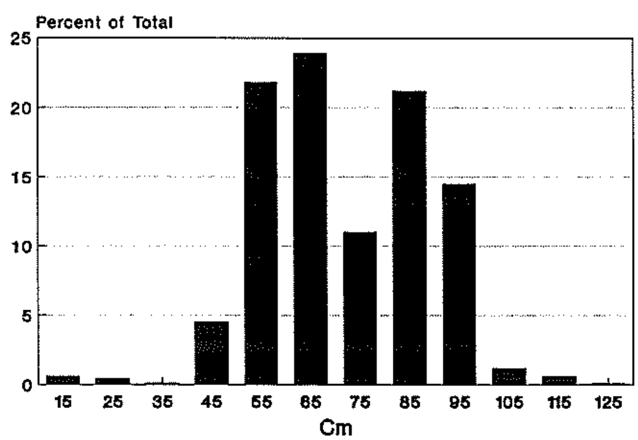

Percent of Total
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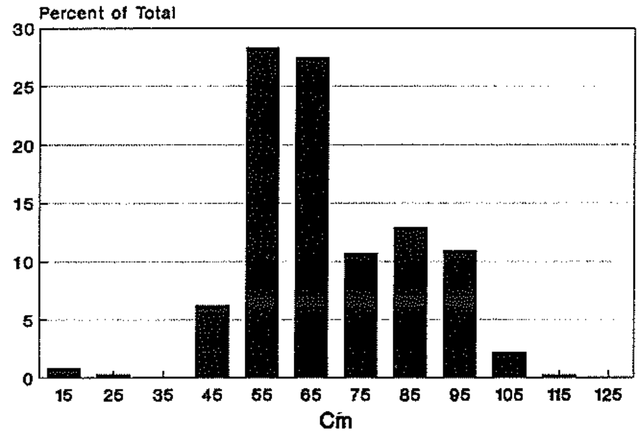
Cm

5(cont)



Percent of Total
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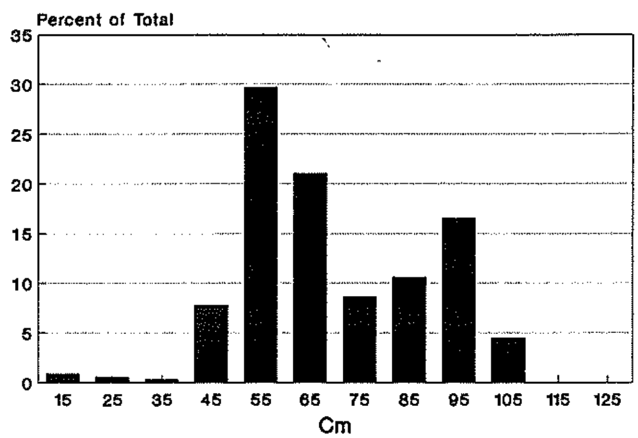

Percent of Total
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30
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10
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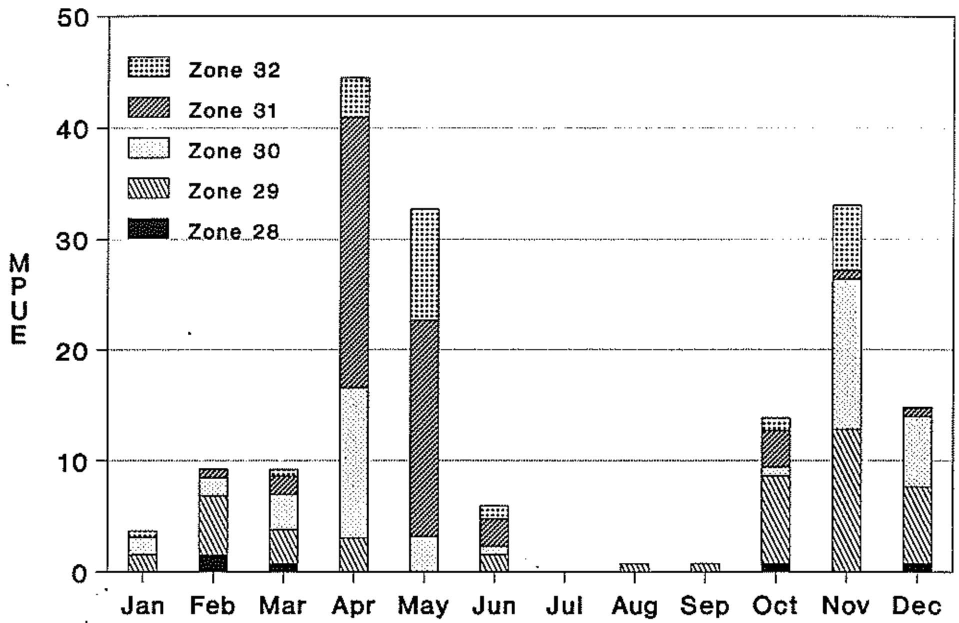
0
15 25 35 45 55 65 75 85 95 105 115 125
Cm

Figure 6



50
40
30
20
10
0
MPUE
Zone 32
Zone 31
Zone 30
Zone 29
Zone 28
Jan
Feb
Mar
Apr
May
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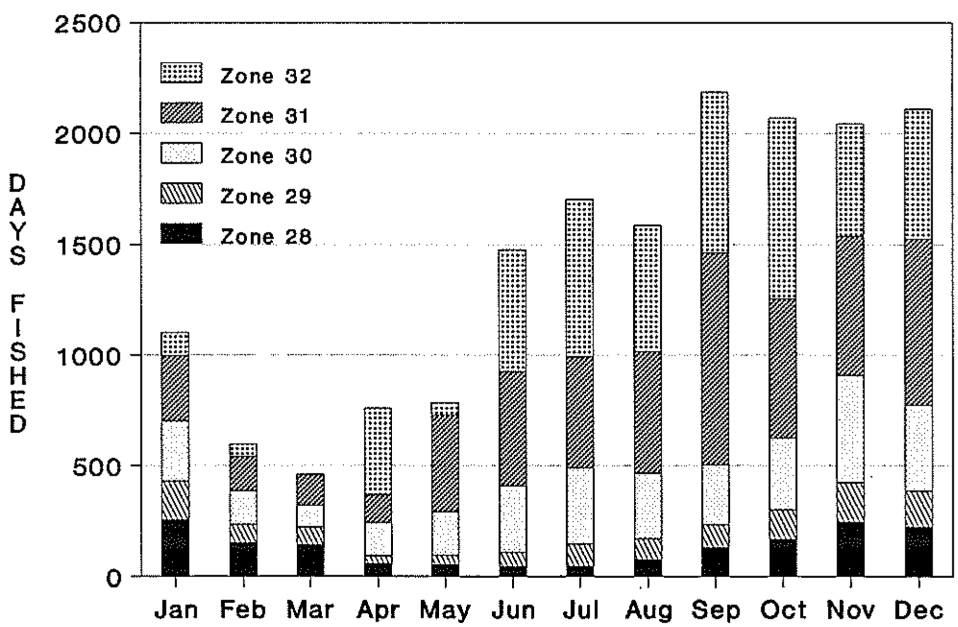
Jul
Aug
Sep
Oct
Nov
Dec



2500
2000
1500
1000
500
0
DAYS FISHED
Zone 32
Zone 31
Zone 30
Zone 29
Zone 28
Jan
Feb
Mar
Apr
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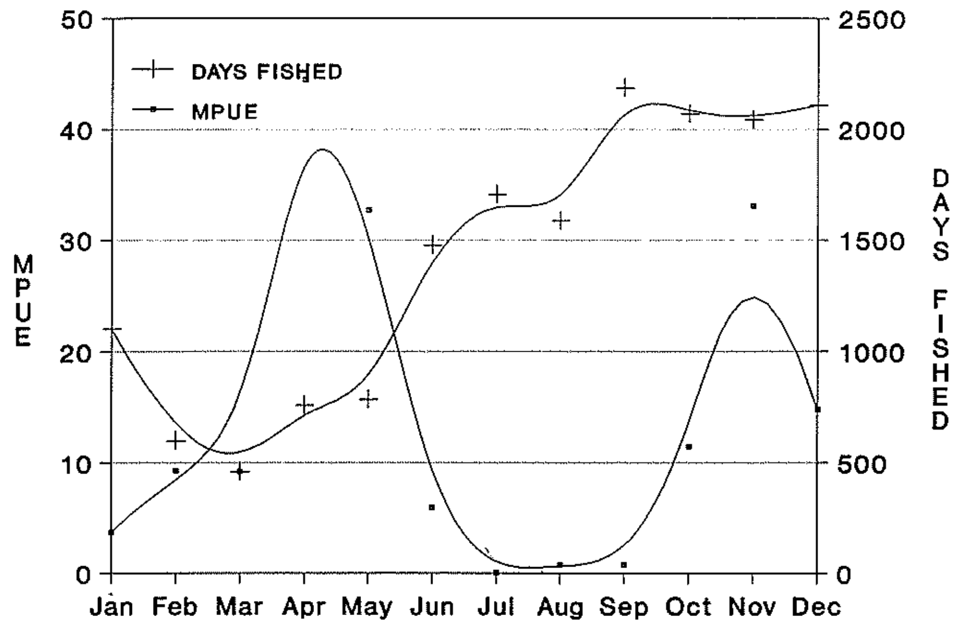
Aug
Sep
Oct
Nov
Dec


DAYS FISHED
MPUE
MPUE
DAYS FISHED
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30
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0
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1500
1000
500
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

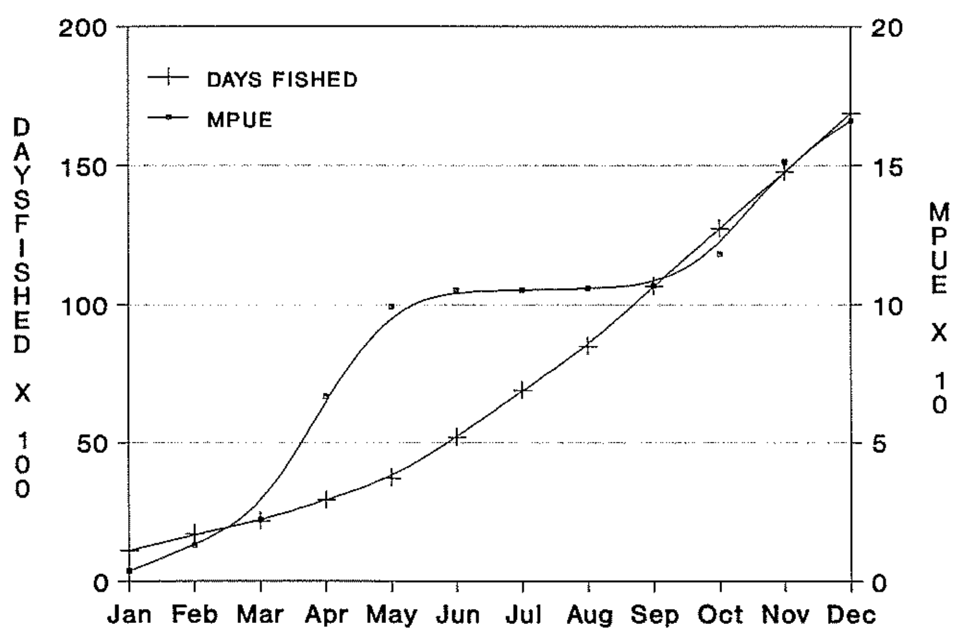
DAYS FISHED
MPUE
DAYSFISHED X 100
MPUE X 10
200
150
100
50
0
20
15
10
5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Figure 7